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Technical Memorandum

*Generation of Oyster Survival Salinity Dose-Response
Curves using Nestier Tray data*

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September 4, 2015

• **Deepwater Horizon Oil Spill** •

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TECHNICAL MEMORANDUM

SUBJECT: Generation of Oyster Survival Salinity Dose-Response Curves using Nestier Tray data

DATE: September 4, 2015

TO: Marla Steinhoff, NOAA; Mary Baker, NOAA; Henry Roman, IEC

FROM: Shahrokh Rouhani, NewFields; Jacob Oehrig, NewFields

INTRODUCTION

Following the Deepwater Horizon oil spill (DWH spill) in April 2010, the state of Louisiana opened two water control structures in the Mississippi River in attempt to minimize the amount of oil reaching the shore (Rose et al. 2014). These structures directed large amounts of river water into Barataria Bay (through the Davis Pond structure) and Black Bay/Breton Sound (through the Caernarvon structure). Figure 1 depicts the locations of the river water diversion structures and their respective basins of influence. The Caernarvon diversion was opened three days after the explosion (April 23, 2010) and remained open through the first two weeks of August with flow at or near maximum capacity (approximately 8,000 cubic feet per second (cfs)). The Davis Pond diversion remained open from May 8 through September 10, 2010, with flow ranging from 7,000 to 10,000 cfs. The 2010 opening of these structures was atypical in that they remained open longer than usual and maintained high flow rates during the spring and summer seasons when they are usually closed. As shown by Figures 2 and 3, the average river water flow through Caernarvon and Davis Pond diversions during the spring and summer months of April – September were elevated during 2010 compared to flow rates over the same time period in preceding and following years. Substantial river water releases can lead to salinity drops that may have impacts on marine fauna such as oysters, which are especially susceptible due to their limited mobility. In order to determine the level and temporal extent of the fresh water's deleterious effects on oyster survival, salinity dose-response curves were created using in-situ oyster survival data collected from Louisiana Department of Wildlife and Fisheries (LDWF) annual Nestier Tray studies.

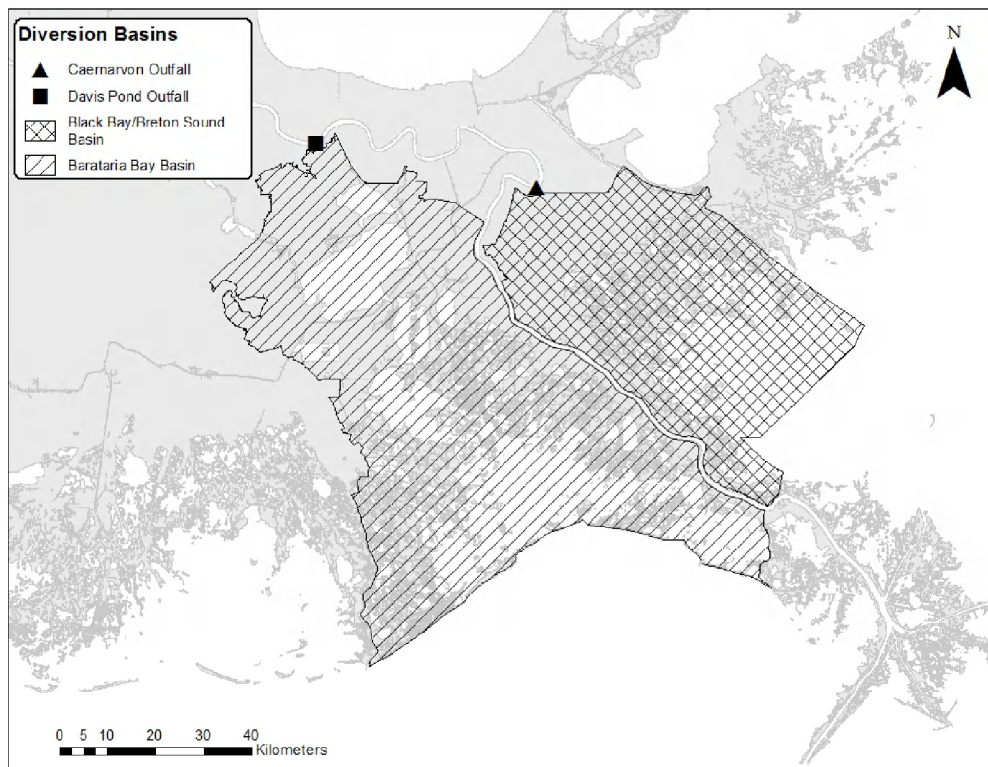


Figure 1- Mississippi River diversion outfall locations and their respective basins of influence.

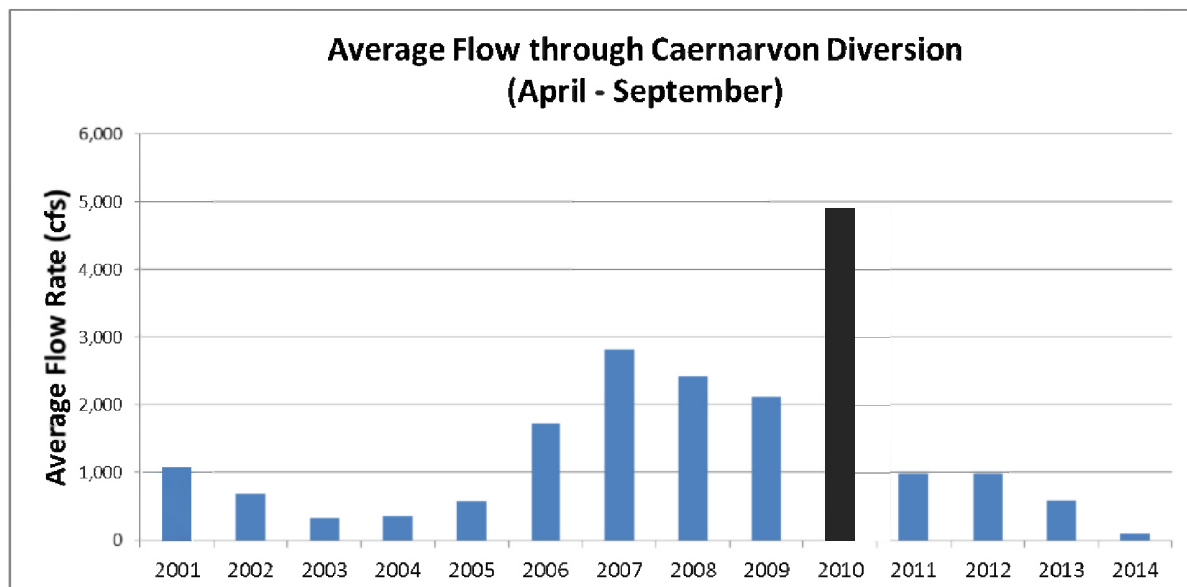


Figure 2 Average flow rate through the Caernarvon diversion during the months of April – September for each year

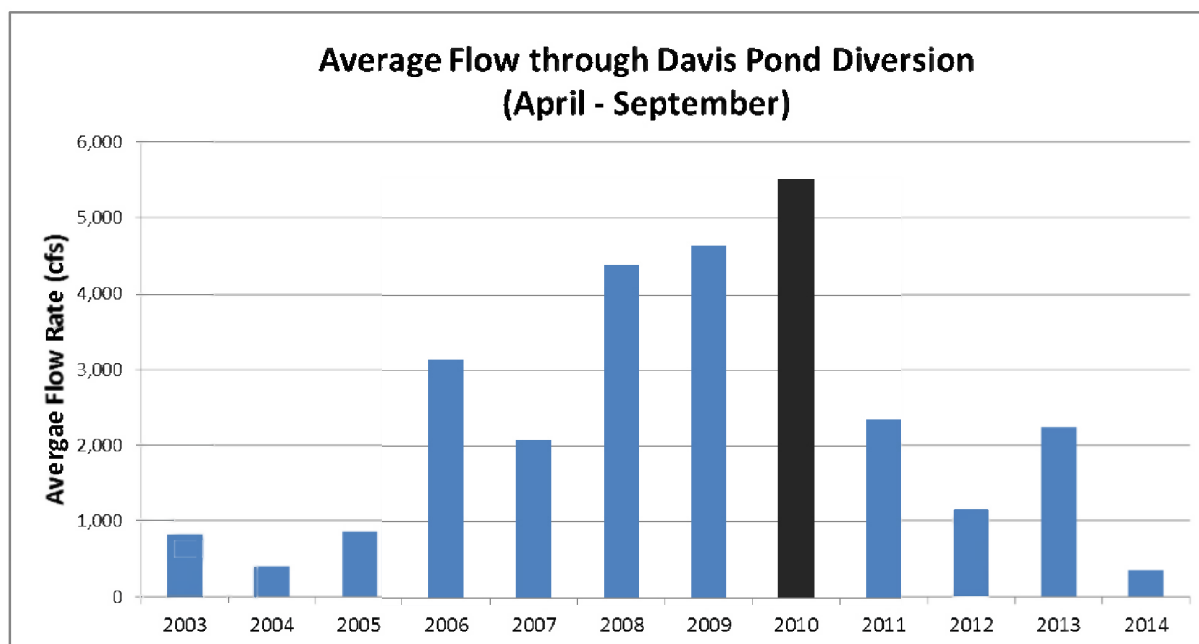


Figure 3 Average flow rate through the Davis Pond diversion during the months of April – September for each year

DATA SOURCES

Nestier Tray Data

During 2007 through 2012, the LDWF conducted annual oyster survival studies in multiple regions along the coast of Louisiana. For these studies, 20 seed-sized oysters were affixed to 70 cm by 70 cm by 7.6 cm Nestier trays and deployed on the seafloor in January of each year. Table 1 provides summary statistics of the size of oysters used in the Nestier trays each year. Each month, LDWF examined the trays and recorded data on individual oyster status, such as whether they were “alive”, “dead”, or “missing”.¹ Nestier tray survival data collected from within Barataria Bay and Black Bay/Breton Sound were used in this analysis. The locations of these trays are shown in Figure 4.

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1. Live/dead status was assigned by tapping each oyster’s shell to see if it responds, and examining shells for presence of predators, fouling organisms, or identification of an empty box.

Table 1 Summary statistics of oyster lengths deployed in the Nestier Trays each year

Year	Number of Oysters	Avg Length (mm)	Min Length (mm)	Max Length (mm)	Std Dev (mm)
2007	1171	69.8	40	111	9.0
2008	1168	73.8	48	104	8.8
2009	1156	71.0	43	102	9.7
2010	1170	68.8	43	106	8.5
2011	1193	71.6	48	97	7.4
2012	473	77.2	48	99	7.3
All Years	6331	71.5	40	111	8.9

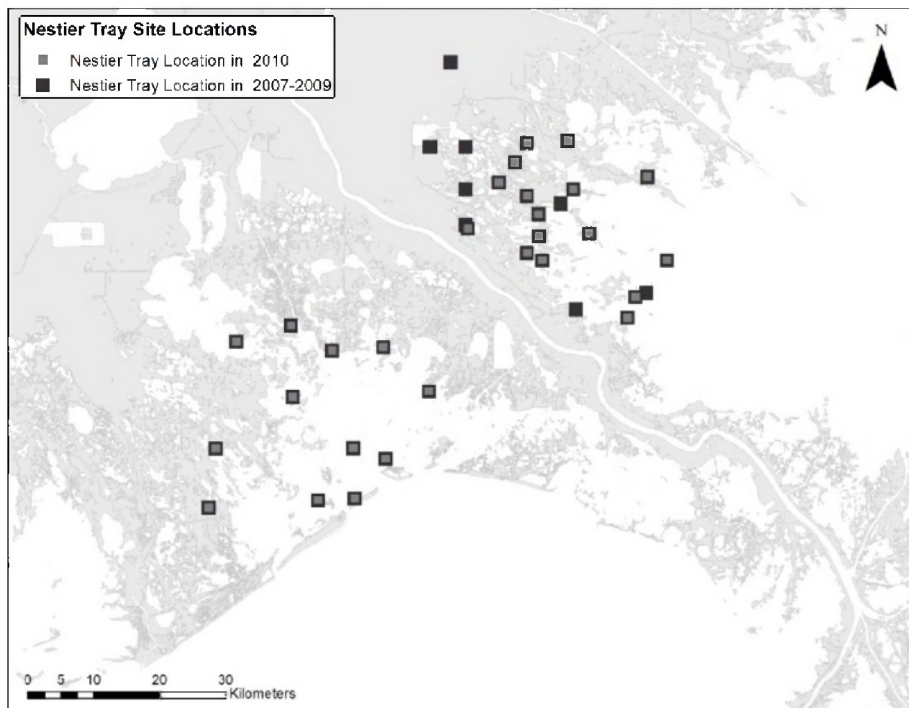


Figure 4 Locations of Nestier trays used in the analysis

Modeled Salinity Data

Daily average salinities for 2006 through 2012 were estimated using a spatio-temporal kriging model fit to an extensive dataset of water quality observations in Barataria Bay and Black Bay/Breton Sound (McDonald *et al.*, 2015). The model incorporated both continuous (hourly or daily) monitor data and discrete measurements of water quality to estimate daily salinities for each cell in a dense 200-meter by 200-meter grid that overlaid the respective basins. The model relied upon salinity data collected by the Louisiana Department of Wildlife and Fisheries (LDWF), the Louisiana Office of Coastal Protection and Restoration (LOCPR), the Louisiana Department of Health and Hospitals (LDHH), the Louisiana Department of Environmental Quality (LDEQ), the United States Geological Survey (USGS), and

measurements recorded during DWH natural resource damage assessment (NRDA) oyster sampling. The locations of water quality/salinity monitoring stations are shown in Figure 5.

The results of the model were subjected to two hold-out cross-validation procedures which yielded statistically significant correlations between measured and predicted values across multiple years and basins. Therefore, the model results can be reliably used in estimating salinity conditions at locations and days where physical water quality measurements were not collected. A detailed description of the model and its validation results can be found in McDonald et al. (2015).

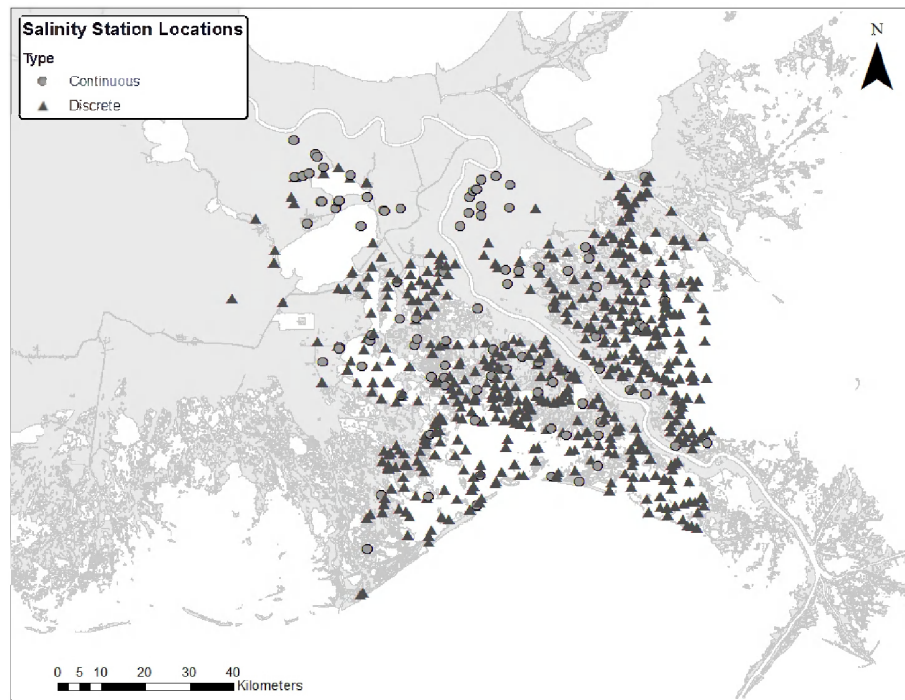


Figure 5 Location of salinity stations used in spatio-temporal kriging model

METHODOLOGY

Nestier tray data from the Barataria Bay and Breton Sound basins were used to develop dose-response curves relating oyster survival to fresh water exposures during the months of April through September. April through September was used as the temporal range of investigation as this is when the river water from the diversions would have reached the oyster study areas (Powers *et al.*, 2015). Using the spatial-temporal salinity model, doses were computed and measured as the maximum number of consecutive days with salinity below 5 parts per thousand (ppt) at each Nestier tray location. When calculating the maximum number of consecutive days, periods of low salinity (i.e., below 5 ppt) separated by temporary salinity increases lasting three days or fewer were considered as part of the same consecutive low salinity

period. Oyster survival percent was used as the response variable and was calculated for each Nestier tray by determining the number of oysters that remained alive from April through September of each year.

Only Nestier trays with at least 50 percent of the originally affixed oysters remaining alive as of April of each year were included in dose-response modeling in order to exclude trays with high mortality caused by factors unrelated to fresh water exposure. Due to the unavailability of survival data prior to June 2006, all 2006 Nestier tray data were excluded from subsequent analyses. Data from four Nestier trays in Barataria Bay were also excluded due to their location in marine environments, which often experience increased mortality as a result of enhanced predation in their more saline waters (Gunter, 1955).

Nestier tray survival and location-specific salinity data covering April through September were combined across both Barataria Bay and Breton Sound basins and used to develop two inhibitory dose-response curves for the period from 2007 through 2012, excluding 2010, as well as for 2010 only, utilizing Equation 1.

$$\text{Equation 1: } Y = \text{Bottom} + \frac{(\text{Top} - \text{Bottom})}{1 + 10^{((\text{Log IC}_{50} - \log(X)) * \text{Hillslope})}}$$

Where:

Y = modeled oyster survival percentage

X = number of consecutive days with salinity below 5 ppt

Top = upper plateau of the curve, which is consistent with survival rate when 0 days of fresh water influence occurred. For this analysis, 100% survival at the 0 consecutive days of low salinity was assumed, so Top was set to 1.

Bottom = lower plateau of the curve, which is consistent with minimum survival when exposed to fresh water. For this analysis, 0% survival was assumed after many days of exposure to fresh water, so Bottom was set to 0.

IC50 = represents the number of consecutive fresh water days below 5 ppt that yields a 50% survival rate. This value was determined iteratively by minimizing the root mean square as described below.

Hill slope = describes the steepness of the family of curves. A Hill slope of -1.0 is standard and was used in all curve-fitting processes.

In the curve-fitting process, the Top, Bottom, and Hillslope variables were treated as constants of 1, 0, and -1, respectively. Using the Root Mean Square (RMS) criterion, survival values from the Nestier tray data were compared to those modeled by the dose-response curves. To minimize the RMS, an iterative process of machine learning algorithm, in this case the *Solver* dialog within Excel was used to determine the IC50.

RESULTS

As shown in Figures 6 and 7, there is little difference between the two fitted dose-response curves. As a result, subsequent analyses relied on the 2010 curve. The resulting equation and parameters used for this curve are shown in Equation 2.

$$\text{Equation 2: } Y = \frac{1}{1+10^{((1.18+1-\log(X))*-1)}}$$

Where:

Y = modeled oyster survival percentage

X = number of consecutive days with salinity below 5 ppt

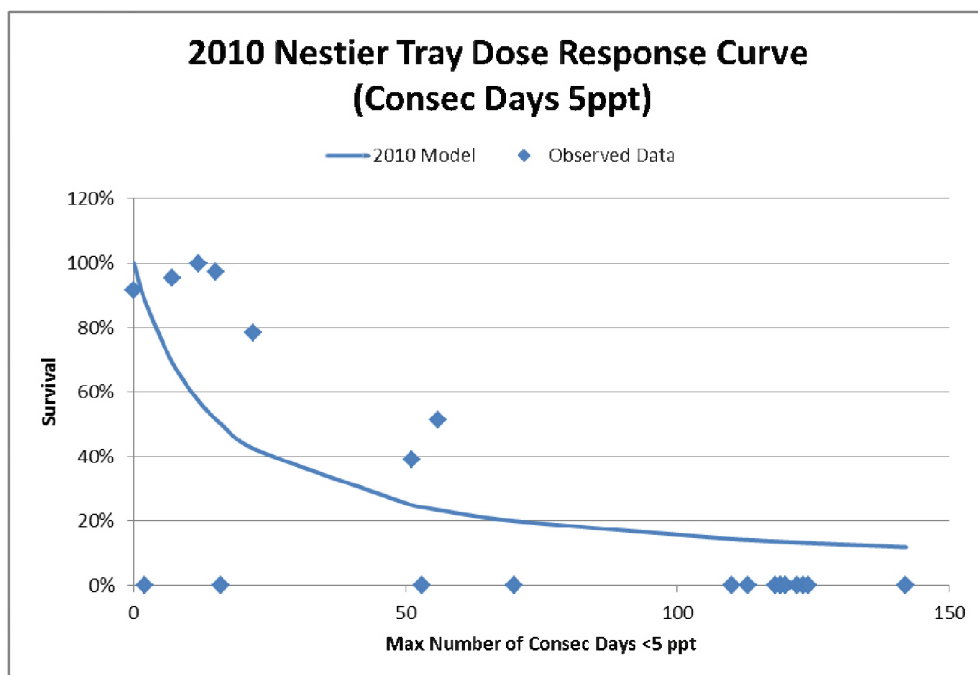


Figure 6 Observed 2010 Nestier tray survival data with fitted 2010 dose-response curve

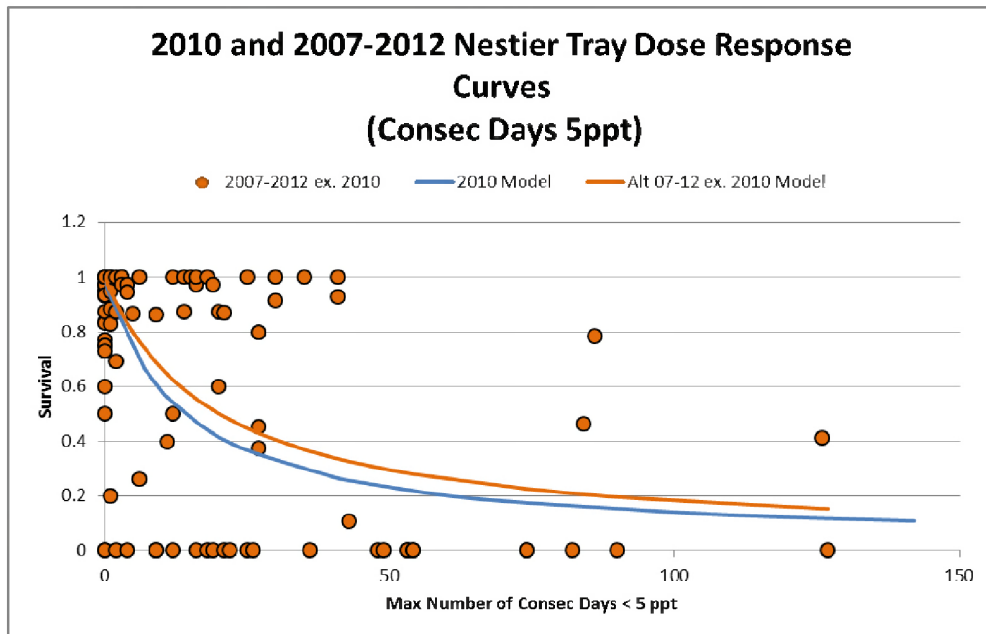


Figure 7 Observed 2007-2012 (excluding 2010) Nestier tray survival data with both fitted dose-response curves

Using the 2010 dose-response curves and results from the salinity model, the decrease in the oyster survival rate at each 200 m² grid cell from the salinity model due to the 2010 freshwater diversion exposures was calculated as the difference between survival rate based on the maximum number of consecutive low-salinity (below 5ppt) days in 2010 and the survival rate based on the average historical (2006-2009) maximum of consecutive low-salinity days at the same cell. Grids with higher predicted survival in 2010 than prior years were assumed to have a zero decrease in survival. All grids indicating a decrease in oyster survival were combined into a comprehensive polygon per basin (Figure 8). This polygon represents the spatial extent of areas in which oysters, if present, would be expected to show decrease in survival due to exposure to fresh water from the diversion openings in 2010.

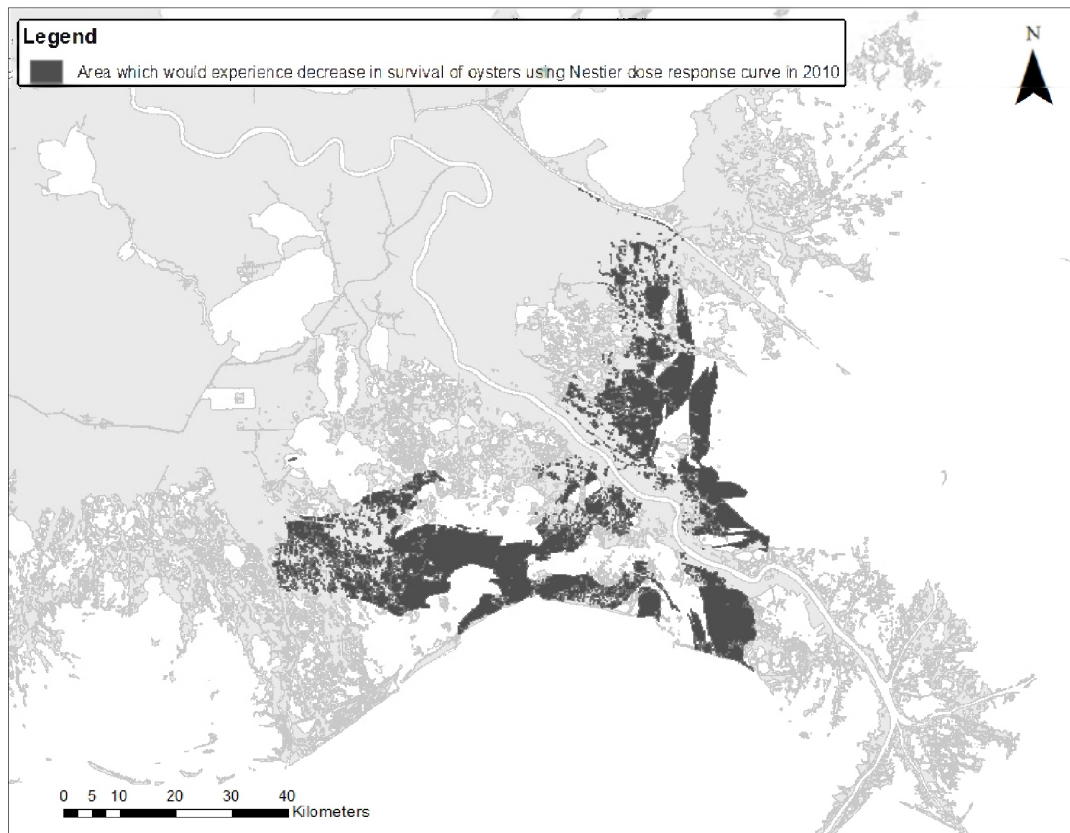


Figure 8 Areas which indicate decrease in oyster survival in 2010 compared to average conditions in 2007-2009 using the 2010 Nestier salinity-survival dose response curve. This polygon represents the spatial extent of areas in which oysters, if present, would be expected to show decrease in oyster survival due to exposure to fresh water from the diversion openings in 2010.

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